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PATENT- OG VAREMÆRKESTYRELSEN

Flow distributing unit and cooling unit

This invention relates to a flow distributing unit which is suitable for a variety of cooling applications, and in particular for liquid cooling of power semiconductors. The invention also relates to a cooling unit employing such a flow distributing unit.

Semiconductor devices generate heat during their operation, and this heat usually acts to degrade the operation of the semiconductor device. For power semiconductor devices it is necessary to be cooled during operation to maintain acceptable device performance, and for high power semiconductors liquid cooling is often applied.

US 5,841,634 discloses a liquid-cooled semiconductor device. The semiconductors are here placed inside a housing on a plate which is to be cooled. The device shows a fluid inlet port and a fluid outlet port, and a baffle placed in a chamber inside the housing. The baffle includes a wall separating the chamber into a top portion and a bottom portion, and walls separating each portion into compartments. A number of holes in the wall between top and bottom portion provide fluid communication between the portions. Fluid is led from the inlet port to a first bottom compartment, and then through holes to a first top compartment. In the top compartment the fluid is led along the plate to be cooled, and through holes to a second bottom compartment. From the second bottom compartment the fluid is led to a second top compartment, where it cools another area of the plate to be cooled. After having passed three top compartments the fluid it led to the fluid outlet port, and out of the device. Thus the cooling compartments of the device are connected in a serial manner.

As the fluid passes the first top compartment, it takes up heat from the plate to be cooled and thus leaves the first top compartment at a higher outlet temperature than the inlet temperature. When the fluid then reaches the second top compartment, additional heating of the fluid will take place, and this will lead to a temperature difference on the cooled plate, from fluid inlet port end to fluid outlet port end. This is detrimental to the lifetime of such a power semiconductor device as high power semiconductors are very sensitive to temperature variations and also sensitive to the general temperature level.

Also the serial connection of multiple cooling compartments will have a high flow resistance as a result, leading to a high pressure drop or a low flow rate of the fluid through the cooling device.

It is an object of this invention to provide a flow distributing unit, and a cooling unit employing such a flow distributing unit, which leads to less variation in temperature along the cooled surface than previously known units.

It is a further object of this invention to devise such units which operate with less flow resistance than previously known units.

It is a further object of this invention to devise a low-cost construction of such units which is particularly suitable to mass production.

In accordance with claim 1, these and other objects are achieved with a distributor for distributing a flow of liquid over a surface to be cooled, the distributor comprising an inlet manifold, an outlet manifold and a plurality of flow cells connected in parallel between the manifolds, each flow cell comprising a cell inlet in fluid communication with the inlet manifold, a cell outlet in fluid communication with the outlet manifold and a flow channel for guiding a flow of liquid from the cell inlet along the surface to the cell outlet. Thus cooling liquid will flow into all cells with substantially the same inlet

temperature. This improves temperature uniformity along the cooled surface. In a typical application where the cooled surface is in thermal contact with power semiconductor circuits, this improves the circuit lifetime. Furthermore the distributor exhibits less flow resistance than the known unit as liquid only passes one cell on its way through the unit and plural cells are connected in parallel between the inlet and outlet manifolds.

Advantageously each flow channel is formed to cause a plurality of changes in the direction of flow of the liquid flowing along the surface as indicated in claim 2. This causes turbulence and changes in the flow pattern of the liquid within the cells. Liquid which has been heated by passing closely along the cooled surface, will be effectively mixed with colder liquid which has not passed along the cooled surface. This ensures that the full heat capacity of the liquid is put to use in the cooling process.

Preferably the flow distributor is formed as a single body having the characteristics set out in claim 3. This allows for the mass-production of the distributor at low cost, for example by injection moulding from thermoplastic material.

Now having described the invention in general terms, preferred embodiments of the invention will be described in details with reference to the drawings, showing:

Fig. 1: An exploded view of a cooling unit
Fig. 2: A perspective top view of a flow distributing baffle
Fig. 3: A top view of the distributing baffle
Fig. 4: A perspective bottom view of the distributing baffle
Fig. 5: An exploded top view of a clamp-on cooling unit
Fig. 6: An exploded bottom view of a clamp-on cooling unit
Fig. 7: A perspective bottom view of a flow distributing baffle in the clamp-on cooling unit

Fig. 8: A perspective top view of the distributing baffle in the clamp-on cooling unit

Fig. 9: An exploded view of a one-piece flow distributor for cooling purposes, shown in front of a plate to be cooled

Fig. 10: A perspective back view of the one-piece flow distributor.

Turning now to Fig. 1, a cooling unit 1 includes a housing 13, formed as a box with a flat back plate 11 and side walls 20 which extend from the back towards a main opening at the front of the box. The housing 13 has an inlet opening 15 and an outlet opening 14 for liquid connections from a pipe system or the like.

A baffle 4 fits with the internal surfaces of the side walls 20 of the housing 13. When the baffle 4 is placed in the housing 13, it divides this into a top compartment and a bottom compartment. The bottom compartment is formed between the back plate 11 and the baffle 4, and is further divided into two chambers or manifolds, as will be described later. The openings 14 and 15 are in fluid communication with the bottom compartments.

A top plate 3, the lower surface of which is to be cooled, closes the top compartment when it is mounted on the main opening on the housing 13, by the intermediate of a sealing ring 16. This sealing ring 16 fits into a groove 17 of the housing 13, and seals between the side walls 20 and the top plate 3. The top plate 3 is fixed to the housing 13 by means of screws (not shown in the drawings), which are screwed into holes 18 of the housing 13 through holes 19 in the top plate 3. The top plate 3 will be referred to as the cooled plate, since this plate is cooled by liquid led through the cooling unit. If the cooling unit is employed to cool power semiconductor circuits, the circuits may be arranged on top of the cooled plate 3 in a manner that will be obvious to those skilled in the art. Of course the cooling unit may be employed to cool

various other sources of heat such as a hot gas or liquid flowing along the exposed surface of the cooled plate 3.

Fig. 2 shows the baffle 4, in a perspective view slightly more angled than at Fig. 1. Visible in this view are inlets 5 and outlets 6, the location of which was indicated in Fig. 1 by the same reference numeral. The top view of the baffle 4 in Fig. 3 shows the inlets 5 and outlets 6 even more clearly. Liquid flows from the bottom compartment to the top compartment through the inlets 5. While in the top compartment, the flow of liquid is directed along the cooled surface (the bottom surface) of the top plate 3 by guiding wall sections 21 which extend upwards from the center plane of the baffle 4, as indicated by arrows in Fig. 3. The flow then returns from the top compartment to the bottom compartment through the outlets 6.

As will be easily seen in Fig. 3, the guiding wall sections 21 leave a meandering flow path for the liquid, by means of an open passage at one end of each wall section. Other wall sections, however, run all the way through the structure, like wall sections 22 and 23. These through-going walls divide the top compartment into cells, each with an inlet 5 and an outlet 6.

As mentioned previously, the bottom compartment is divided into two chambers or manifold. Fig. 4 shows a perspective view of the baffle from the bottom side. A wall section 10, running in a snake-like pattern along the bottom side, will bear on the bottom plate 11 of the housing 13 in substantially liquid-proof abutment. The bottom compartment of the baffle 4 is hereby divided into an inlet compartment or manifold 8 and an outlet compartment or manifold 9, when the baffle is placed in the housing. All cell inlets 5 are in connection with the inlet manifold 8, and all cell outlets 6 are in connection with the outlet manifold 9. The cells of the top compartment, Figure 2 and 3, are thus all connected in parallel between the inlet manifold 8 and the outlet

outlet manifold 9, and thus in parallel between inlet and outlet, positions 15 and 14 of Fig. 1.

The inlets 5 and the outlets 6 are placed such that the outlet of one cell is next to an inlet of another cell. This has the effect that heated liquid, which is about to leave one cell, is close to unheated liquid which has just entered a neighbouring cell. This serves to minimize the heat gradient along the cooled plate 3. The heat gradient along the cooled plate is further minimized by varying the size of the area which the cells covers. Along the edges 12 the area of each cell is larger than on the rest of the surface, whereby the cooling in the area along the edges 12 is less effective than on the rest of the area. This reflects a situation where the density of heat generating elements is lower along the edges of a semiconductor device than on the rest of the device. Lowering the cooling effect along the edges of the cooling unit will improve temperature uniformity across the cooled plate.

In the embodiment of the invention shown in Figs. 1 to 4, it is intended that a substrate with semiconductors be placed on top of the cooled plate 3, in a way known to those skilled in the art. The cooled plate could however be the substrate itself, placed directly as a cover on the cooling unit. This is a consequence of the minimized heat gradient along the cooled plate, which makes the traditional heat spreading plate, shown in Figure 1 as the cooled plate 3, superfluous in some applications.

Figs. 5 to 8 show several views of a similar cooling unit with dimensions adapted for cooling a microprocessor, a video display processor or a similar high-density processing chip in a personal computer, a server computer or the like. The unit is intended to be clamped on top of the circuit to be cooled. Elements corresponding to elements shown in Figs. 1 to 4 are marked with the same reference numerals. It should be noted that in Figs. 5 to 8 the back

plate 11 is shown detached from the unit whereas in Figs. 1 to 4 the cooled plate 3 is shown detached from the unit.

Fig. 9 shows an exploded view of a one-piece flow distributor 13 for cooling applications in front of a plate 3 to be cooled. Fig. 10 shows the back side of the flow distributor.

The unit shown in Figs. 9 and 10 is adapted for manufacturing by die casting or injection moulding. It is made as one single piece without the separate baffle of Figs. 1 to 9.

In Fig. 10, a side wall 20 at the periphery of the back plate 11 extends from the front side of the back plate 11 towards the main opening of the flow distributor, which in use is closed by the plate to be cooled as shown in Fig. 9. Furhtermore the front side of the back plate 11 carries an inner wall structure. The inner wall structure is made out of number of first wall segments 22 and 23 which delimit four flow cells 26, 27, 28 and 29. Second wall segments 21 define a meandering flow path in each flow cell.

On its back side, the back plate 11 is formed with an inlet tube 25 which leads to an inlet opening 15, and with an outlet tube 24 which leads to an outlet opening 14. The bore of both tubes is traversed by portions 30 and 31 of the first wall segments 22 and 23 which run at right angles to each other. This creates four cell inlets 5 at the inner end of the inlet tube 25, and four cell outlets 6 at the inner end of the outlet tube 24. Each cell inlet 5 admits liquid to one of the flow cells 26 through 29 from the inlet tube 25, and each cell outlet passes liquid from one of the flow cells 26 through 29 to the outlet tube 24. In other words, the short inlet and outlet tubes cooperate with the traversing portions of the inner wall structure to act as very low volume inlet and outlet manifolds.

The configuration of the inner wall structure is such that there are two flow cells 26 and 28 which cool the center area of the cooled plate, and two flow cells 27 and 29 which cool the periphery of the cooled plate. In the central flow cells the meandering flow path is narrower, and the meandering frequency is higher than in the peripheral flow cells. Channel size and meandering frequency influences the cooling efficiency, and the configuration shown is chosen to adapt the cooling efficiency to the flow of heat expected at the center and at the periphery of the cooled plate.

The overall design of the flow distributing unit of Figs. 9 and 10 is such that it may be manufactured as a single unit, thus dispensing with the use of a separate baffle.

Claims

1. A distributor for distributing a flow of liquid over a surface to be cooled, the distributor comprising an inlet manifold (8, 25), an outlet manifold (9, 24) and a plurality of flow cells (26 - 29) connected in parallel between the manifolds, each flow cell comprising a cell inlet (5) in fluid communication with the inlet manifold, a cell outlet (6) in fluid communication with the outlet manifold and a flow channel for guiding a flow of liquid from the cell inlet along the surface to the cell outlet.

2. A distributor as in claim 1 wherein each flow channel is formed to cause a plurality of changes in the direction of flow of the liquid flowing along the surface.

3. A distributor as in claim 1 or 2 formed as a single body, the body comprising:
- a housing (11, 20);
- a main opening in the housing formed to be closed in a liquid-tight fashion by the surface to be cooled;
- an inlet opening (15) in the housing in fluid communication with the inlet manifold;
- an outlet opening (14) in the housing in fluid communication with the outlet manifold, and
- an inner wall structure (21, 22, 23) cooperating with the housing to define the inlet manifold, the outlet manifold and the plurality of flow cells.

4. A distributor as in claim 3, wherein:
- the housing comprises a back part (11) opposite and at a distance from the main opening, a side part (20) extending from the back part to the main

opening, an inlet part (25) extending to the inlet opening and an outlet part (24) extending to the outlet opening;
- the inner wall structure comprises a plurality of wall sections (21, 22, 23) extending from the back part toward the main opening;
- the inner wall structure cooperates (30, 31) with other parts of the housing to define the inlet manifold; and
- the inner wall structure cooperates (30, 31) with other parts of the housing to define the outlet manifold.

5. A distributor as in claim 4, wherein:
- the inlet part is an inlet tube (25) extending from the back part in a direction away from the main opening;
- the outlet part is an outlet tube (24) extending from the back part in a direction away from the main opening;
- the bore of the inlet tube is traversed by at least one first wall section (30, 31) of the inner wall structure to delimit at least two cell inlets (5) for guiding liquid away from the inlet tube; and
- the bore of the outlet tube is traversed by at least one second wall section (30, 31) of the inner wall structure to delimit at least two cell outlets (6) for guiding liquid toward the outlet tube.

6. A distributor as in claim 4 or 5 wherein the inner wall structure delimits at least one inner flow cell (26, 28) for distributing liquid over a central part of the surface to be cooled and at least one outer flow cell (27, 29) for distributing liquid over a peripheral part of the surface to be cooled.

7. A distributor as in any one of claims 3 to 6 wherein the inner wall structure delimits a meandering flow path along the surface in each cell.

8. A liquid-coolable unit for removing heat from a heat source, the unit comprising a plate heated by the heat source and a distributor as in any

preceding claim for distributing a flow of cooling liquid over a surface of the plate.

9. The use of a unit as in claim 8 for removing heat from an electronic circuit.

10. A liquid-coolable electronic unit, the unit comprising an electronic circuit en-capsulated in a circuit module having an outer surface, and a distributor as in any one of claims 1 to 8 for distributing a flow of cooling liquid over the surface.

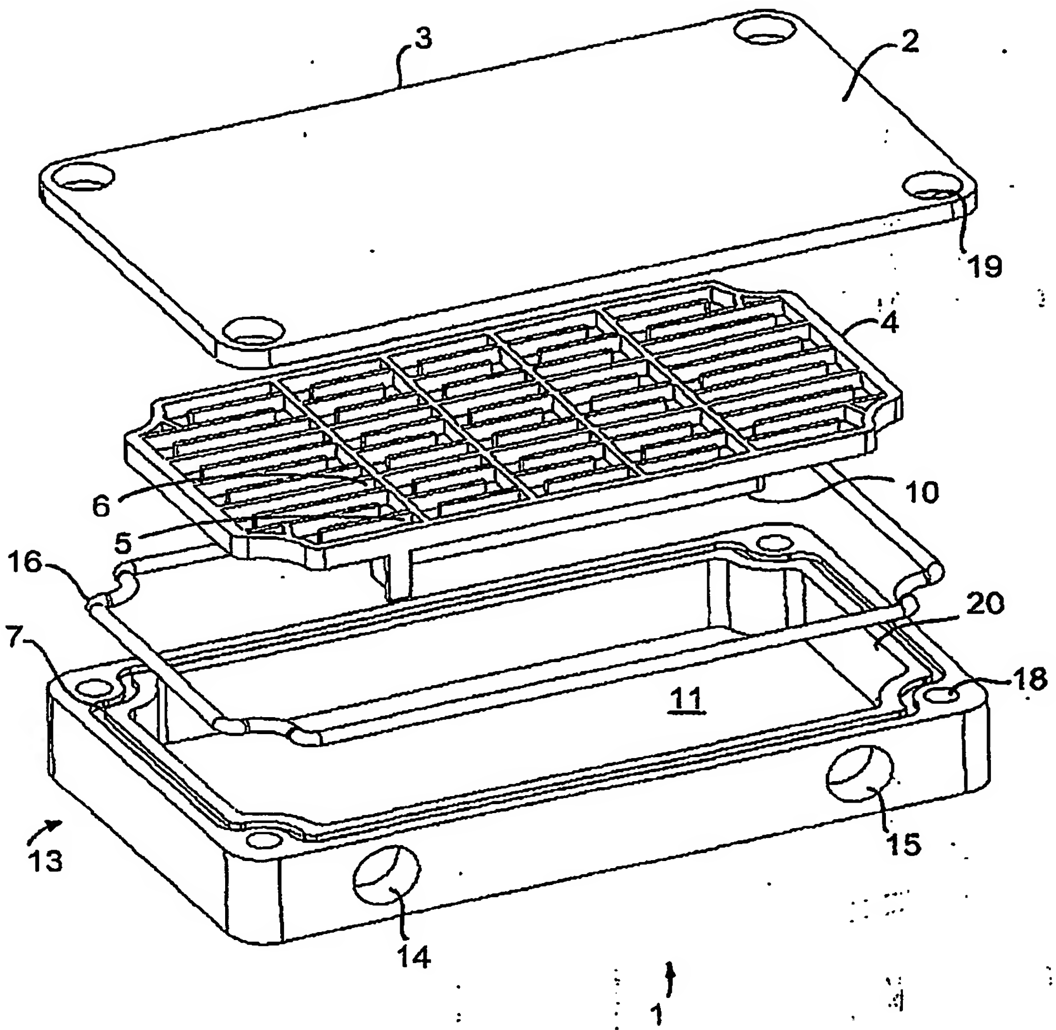


Fig. 1

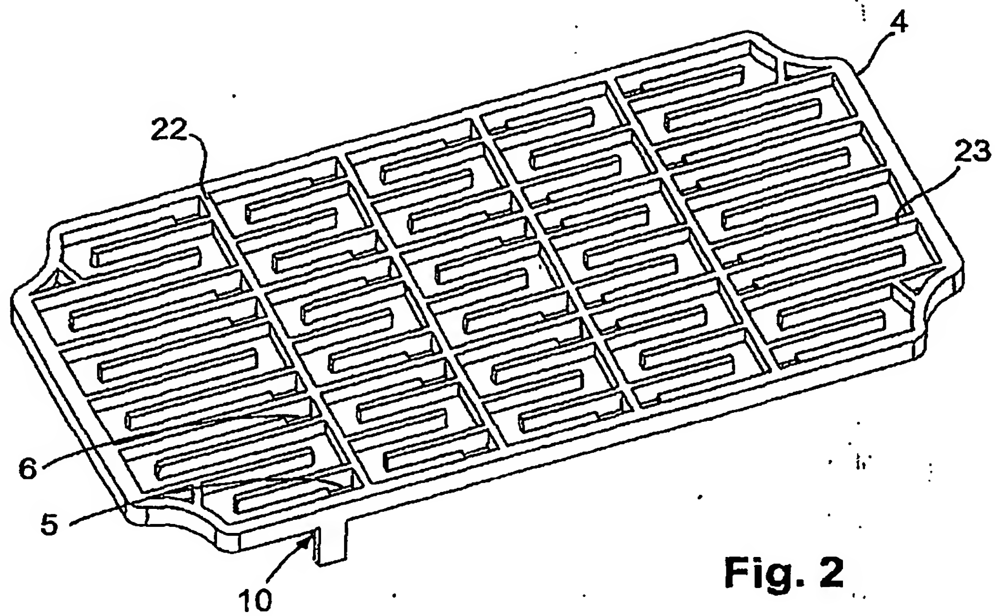


Fig. 2

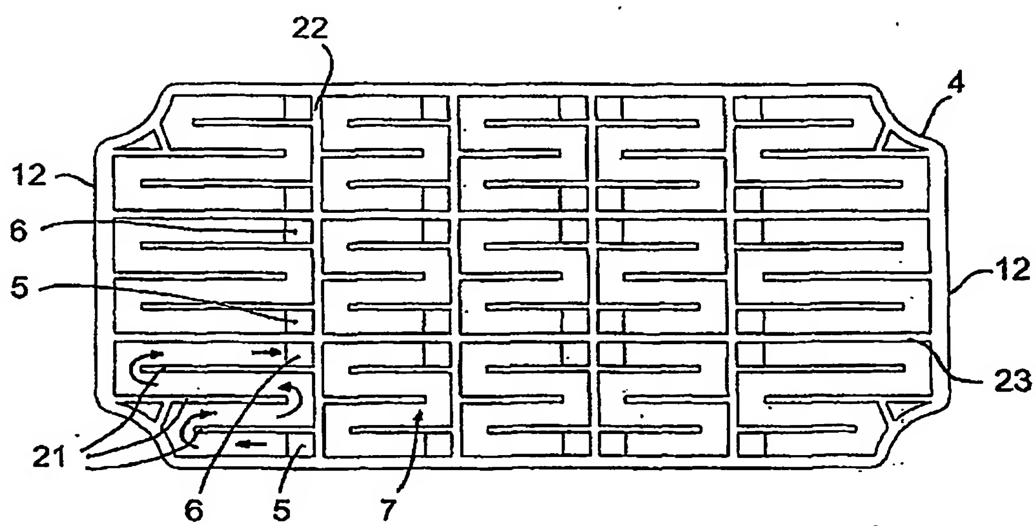


Fig. 3

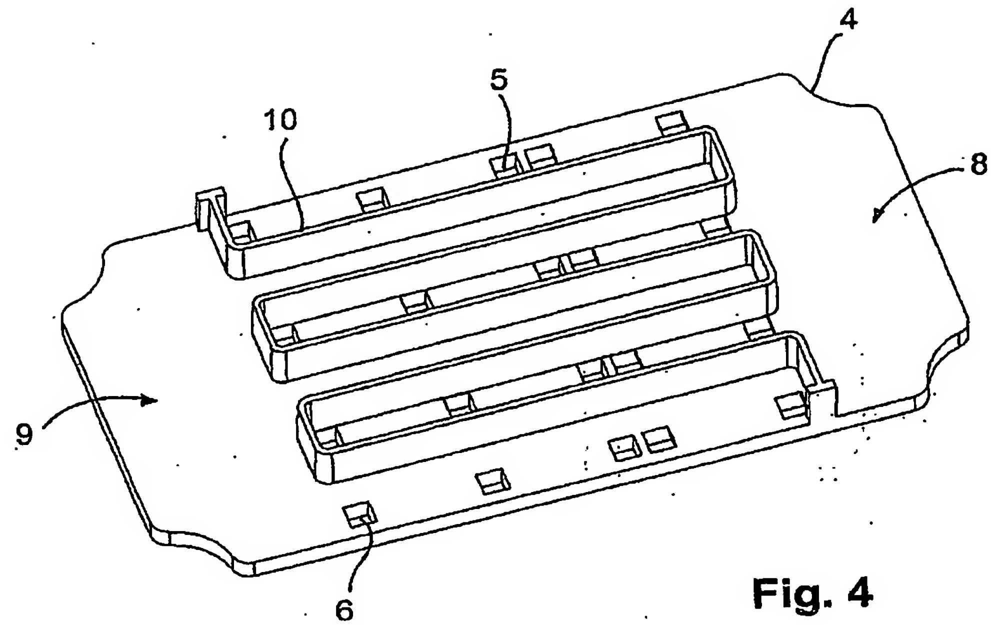
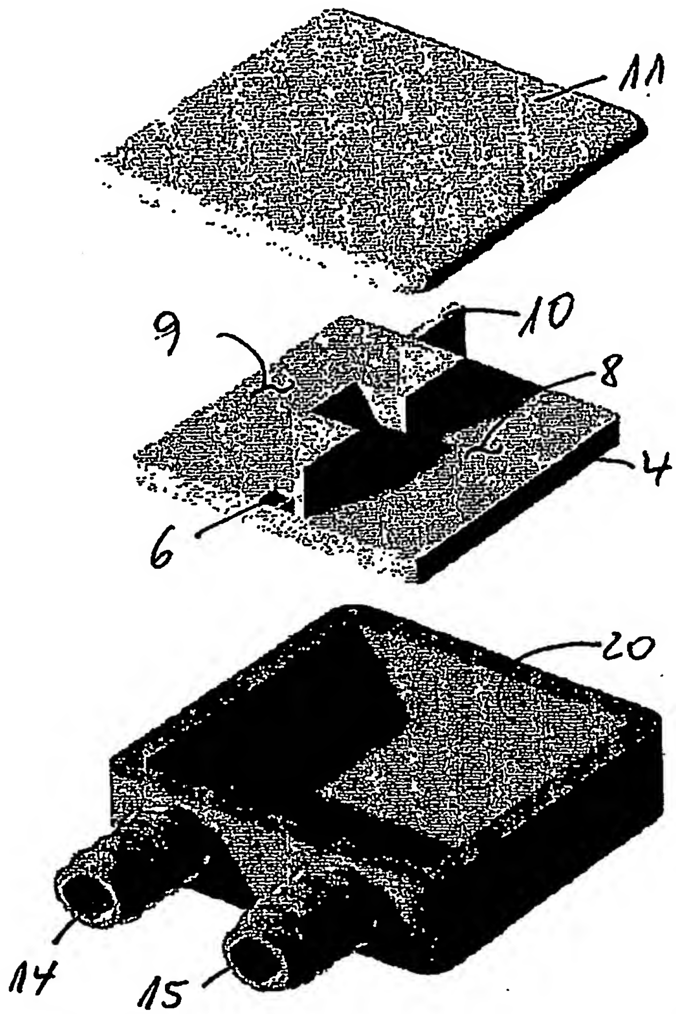


Fig. 4



~~Figure 1. Exploded view of cooler, from top.~~

Fig. 5

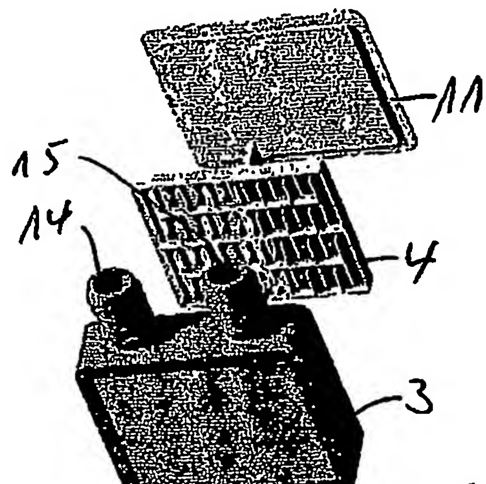


Fig. 6

~~Figure 2. Exploded view of cooler, bottom.~~

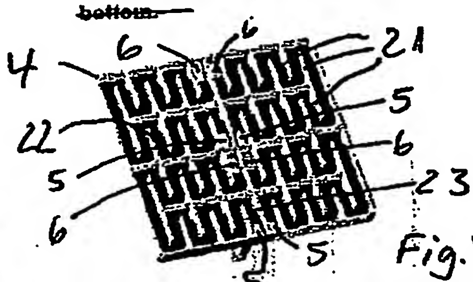
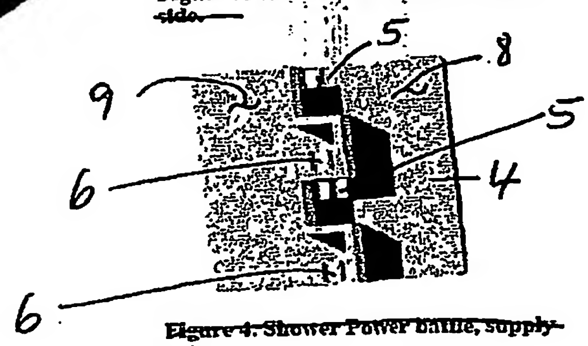


Fig. 7

~~Figure 3. Shower Power baffle, cooler side.~~



~~Figure 4. Shower Power baffle, supply side.~~

Fig. 8

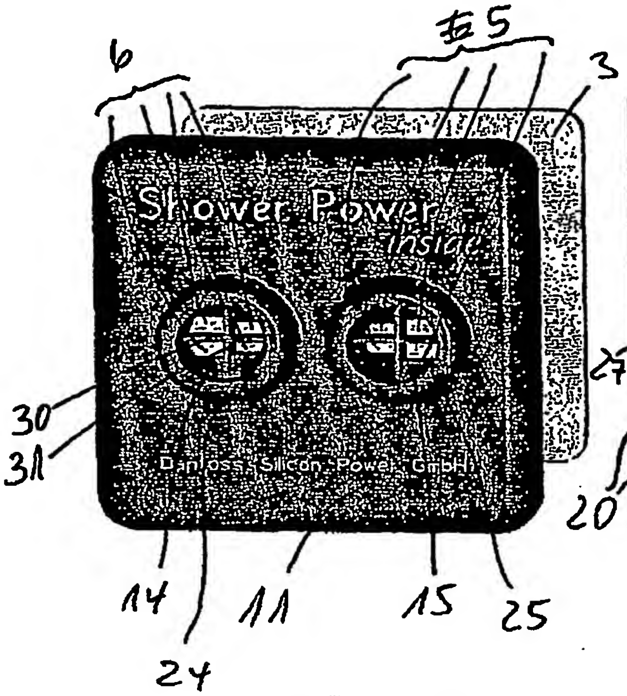

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Fig. 9

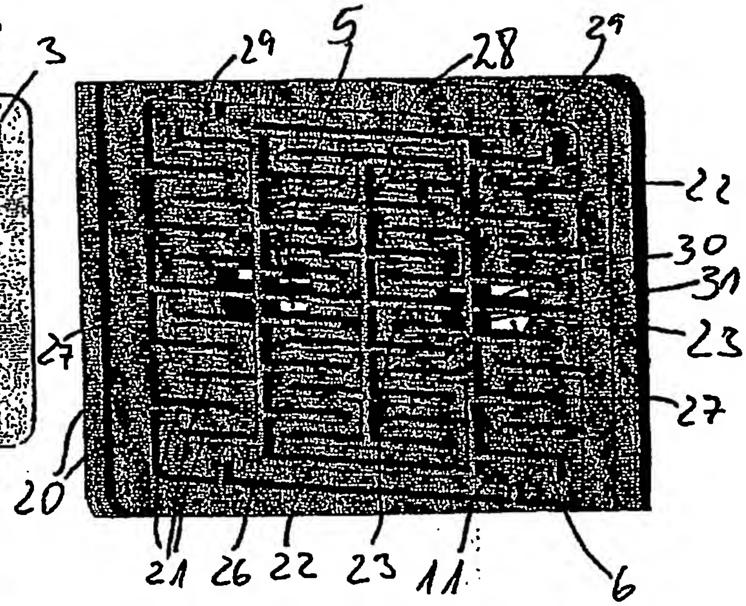
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Fig. 10